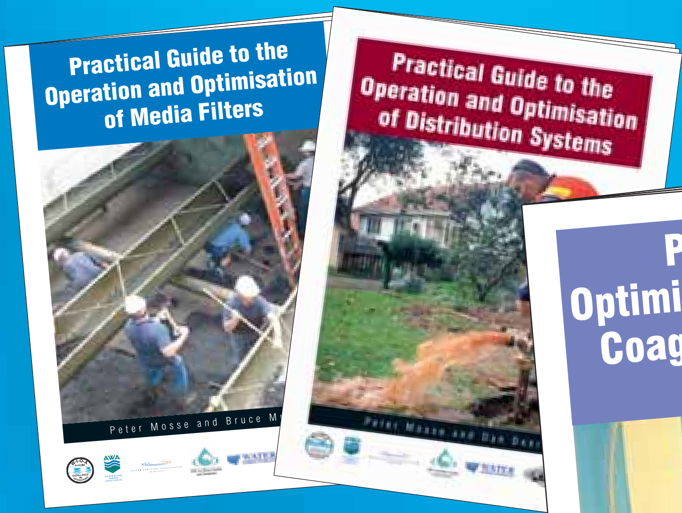
WATERWORKS

W-I-O-A Australia EXCELLENCE IN OPERATIONS

OFFICIAL JOURNAL OF THE WATER INDUSTRY OPERATORS ASSOCIATION

June 2008

Practical Guides to Water Treatment



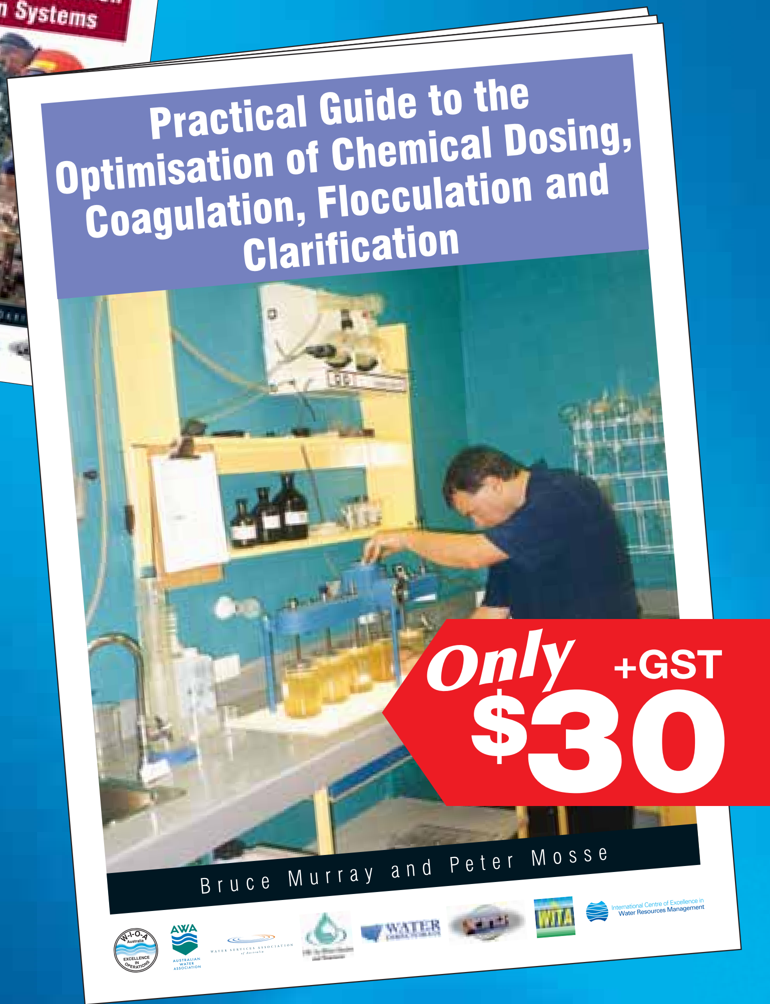
Introduction

In support of the Australian Drinking Water Guidelines Framework for the Management of Drinking Water Quality, Water Industry Operators Association Australia has coordinated the production and distribution of a series of "practical guides" to the operation of key steps (control points) in the delivery of water from the catchment to the consumers tap.

The practical guides are being produced by Australian water industry specialists all with significant practical operational experience in Australian conditions.

The series of five practical guides aimed at water system operators and managers will cover media filters; catchment management issues; chemical addition and primary solids removal; water distribution system operation and disinfection management.

The project is being assisted by financial contributions from the Australian Water Association (AWA), the Water Services Association of Australia (WSAA), the Co-operative Research Centre for Water Quality and Treatment (CRC WQT), the NSW Water Directorate, Pipes Wagga, the Qld Water Industry Training Association (WITA) and the International Centre for Excellence in Water Resource Management (ICEWaRM).



Testimonials

I have just finished reading a copy of your "Filters" publication and after 40 years in the urban and rural water and wastewater industry in Queensland, I'm not easily impressed, but the Guide is excellent. I've already obtained an individual copy for each of my Operators, and I'll be making sure that they know that I think they need to take good note of the Guide. I see that this Guide will be one of a small series of Practical Guides. The quality of this one is so high that I will be purchasing copies of those as they become available. Thank you and your team for all the good work.

***Patrick (Pat) McCourt** - Manager Treatment Processes, Pine Rivers Shire Council, Qld*

I've sat back and had a quiet and objective flick through the Chem Dosing, Coag, Flocc and Clarification Practical Guide. It's a masterpiece!! Seriously, it's right up with the best in terms of a single, practical guide to these very important unit processes in water treatment and at the price, it is unbelievable value!! Congratulations again to WIOA and to the authors Peter Mosse and Bruce Murray for pulling it off. It should prove to be a very valuable reference.

***Peter Gebbie – Principal Engineer** (Process Design), Water Group, SMEC Aust.*

108 full colour pages of information.A resource evey water treatment operator should have!

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Contributions Wanted

WaterWorks welcomes the submission of articles relating to any operations area associated with the water industry. Articles can include brief accounts of one-off experiences or longer articles describing detailed studies or events. These can be emailed to a member of the editorial committee or mailed to the above address in handwritten, typed or printed form. Longer articles may need to be copied to CD and mailed also.experiences or longer articles describing detailed studies or events. These can be emailed to a member of the editorial committee or mailed to the above address in handwritten, typed or printed form. Longer articles may need to be copied to CD and mailed also.

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IT'S JUST NOT GOOD ENOUGH: CAPITAL PROJECT DELIVERY

Something is very wrong with our methods of project delivery. When will the asset managers, contractors and project managers deliver a project that doesn't create endless problems for operators? When will these "professionals" deliver what the operator needs. Sure, nothing can be expected to be completely perfect first time, but the methods of project delivery are almost universally such that as the project nears completion the contractors efforts are directed elsewhere, and the final stages of the delivery suffer dramatically.

Why isn't the training delivered as soon as the client's operators begin operation of the plant? Too often operators are forced to operate a plant without knowing much about it. Manuals are flung about the place but many reflect the individual elements that make up the plant, rather than a meaningful compilation in a full operations manual.

Some examples of recently observed issues include a new combined DAFF/ microfiltration plant where clearly the link between the DAFF contractor and membrane contractor was very much less than seamless, the operators have to shift a pH probe from one beaker at one pH to another beaker at another pH just to keep the plant operating. Not good enough.

Figure 1. The pH probe removed from the process flow and "tricked" by using standard pH buffer solutions.

A valve wasn't working - the operators knew it wasn't working but the contractors insisted it was. Some sort of instrument check during commissioning may or may not have been done but it was ticked off as being checked. Finally, after heaping doubt on the operators, the contractors found that the mechanical mechanism inside the valve was not linked. Come on guys this just isn't good enough.

Figure 2. The valve from hell!!!

Water Utilities - sure you need to go to competitive tendering but how about making sure that this project end attrition doesn't occur. Forget about bickering about the money and who owes what and whether a bank security will be held. Make sure the operator isn't the recipient of these untenable situations. Get it done. How about developing a more significant "last stages" fund into contracts to alleviate many of the hassles at the end and be lucrative enough to entice the contractor back in a timely manner. Contractors – don't sharpen the pencil so much that you can't afford to be around at the end. Utilities are not buying the concrete boxes or landscaping or MCCs etc. They want the functional process. Make sure the price reflects the ability to deliver this without the endless hassles that confront the operator at hand over times.

The stories are endless. The operator has little choice but to be landed in the middle of it all. So we need to make sure that the inevitable things that will and do go wrong are fixed promptly. Many operations teams can't wait to get to the final hand over and get rid of the contractor so that they can fix all the problems and get the plant running properly. Having operators fix things any earlier isn't allowed by the contractor since it may void the contract. Forget this contractual management nonsense and think about the operator. It just isn't good enough, and project delivery teams should make every effort to ensure the often confrontational terminal stages don't leave the operator sandwiched in the middle having to inherit a mess with no way of fixing it.

Peter Mosse
June 2008

Our Cover: John Knoblauch of SA Water checks the chlorination system at Morgan Water Treatment Plant on the Murray River.

PETROL AND SEWER DON'T MIX

Peter Anderson, Barry Young and Chris Seam

Introduction

High level contamination has always been an operator's worst nightmare.

This article details what happens when a large volume of petrochemical finds its way into the sewerage network, the treatment basins of a sewage treatment plant and finally into the tertiary ponds. South Kempsey Petrochemical Incident 13th & 14th December 2007.

Although you think you are prepared for such incidents, the enormous potential impact on your treatment process, the environment and the eventual financial cost cannot be predicted.

On the 13th of December 2007, the South Kempsey Sewage Treatment Plant (STP) Operator started his day as normal!

A petrochemical smell was first noticed during cleaning the bar screens at the head of works. After waiting for the next inflow slug from the pump stations, the operator noticed the smell had increased dramatically and immediately notified the Sewer Technical Officer and then commenced the investigation of the three feeding pump stations to determine the area of possible contamination.

Kempsey is situated on the Mid North Coast of NSW; six hours drive south of Brisbane and three hours north of Newcastle and is the town centre for the Macleay Valley.

About the Plant

The South Kempsey Treatment Plant was built during the 1935 to 1940 era and consists of a basic inlet box, 2 sedimentation tanks and 2 Trickling Filters with a nominal capacity of 3,400 EP. It was upgraded in 1989 with the commissioning of a 2000 EP Pasveer channel to run in parallel with the existing treatment infrastructure as well as a new inlet works comprising Balance tank, course screenings, flow distribution and manual grit removal.

There are also three [3] effluent ponds including a catch pond. The effluent ponds have a detention time of 10 days at ADWF.

The Plant has an average dry weather inflow of 15l/s [1.29Ml/day] and the peak wet weather inflow is 111.4l/s [9.6Ml/day].

South Kempsey has a large catchment comprising 17 council owned pump stations and 4 privately owned pumping stations.

The wastewater transportation system is divided into 3 separate systems that independently discharge to the Wastewater Treatment Works.

Managing the Incident

The Technical Officer in conjunction with the Coordinator advised the Manager of Macleay Water of the potential problem at the plant and an emergency action plan was enacted.

The Coordinator's first priority was to attend the plant and determine the severity of the problem. On arrival the smell of petrol/sewerage mixture was strong.

After an inspection of the plant, the Coordinator updated the Manager, who had set up the Macleay Water's office as a command centre. The "command centre" contacted the authorities for advisement and relaying up to date information.

These authorities included:

- NSW Fire Brigade who attended the plant quickly to take control of the potentially highly explosive area.
- Department of Environmental and Climate Change.(DECC)
- Department of Water and Energy

On site actions were also taking place including:

- Assessment of the plant and barricading the inlet works to isolate the area, because of the potential danger.
- Monitoring of all personnel on site and seeking medical help for the operator who at that stage was complaining of headaches.
- Full cooperation with the NSW Fire Brigade to try to find the source of the problem.

Macleay Water personnel had two main priorities:

- Find and stop the influx of petrochemical into the sewerage network.
- Stop the contamination from entering the environment.

To do this Macleay Water staff split into two teams.

Team One made up of the Council's Environmental and Technical Officers conducted a systematic search of the reticulation system.This was done using of gas monitors to test pump stations and gravity sewer mains to try to determine the source of the Petrochemical.

Team Two had the responsibility to keep the plant environmentally isolated and safe. This was done by:

- Turning the Pasveer aeration off and raise the decant.
- Redirecting the Trickling Filter inflow to the Pasveer.
- Pumping down Tertiary ponds to make room for contaminated effluent.
- Weir placement at outlet of the first tertiary pond

These actions increased the detention time through the works thus giving the petrochemicals longer to evaporate.

The Hazmat team who had been called by NSW Fire brigade then started skimming the top layer of liquid from the Pasveer. The oily liquid was transferred into a 20,000 litre storage tank brought in from another plant. The Pasveer at that stage had all the Plant's inflow entering it, so it too had the top layer of liquid pumped to an empty sludge lagoon.

Later in the day the first team located the source of the contamination!!! A broken petrol bowser line at a local fuel depot. The leaking fuel was caught via an agricultural line that was directed into a wash down area storage pit. The liquid then drained into a large holding tank and pumped directly into a sewer gravity main, which in turn flowed into the pump station.

It was thought that between 1000 and 2000 litres was involved in the incident.

By mid afternoon an update meeting was held at South Kempsey STP.

It was decided:

- The fire brigade would enter the fuel depot and ensure that the petrochemicals had been stopped from coming through the system.
- The sewer gravity mains would be flushed from fire hydrants from both directions to Angus McNeil Pump station.
- Manholes were vented by pulling the lids along the rising main to an area through the museum park.

The mains were flushed four times and each time the Lower Explosive Levels (LEL) dropped in the pump station. After the fourth flush the reticulated sewer system was deemed safe for normal operation.

The Day After!!

During the night the Trickling filter remained on bypass with inflow directed to the Pasveer. The Pasveer remained without aeration and the bypass to the lagoons remained in place.

The following day Council obtained advice from Port Macquarie Hastings Council's Sewerage Coordinator, who conducted bacteria testing to determine the extent of process damage. It was determined that if the Pasveer was "seeded" from an appropriate sewer plant the bacteria in the Pasveer should survive. This was conducted using a pump out truck on that day with a total of 22,000 litres of seed being used.

Aeration was also turned back on to the Pasveer following handover from NSW Fire Brigades Area Commander when the area was deemed safe.

One trickling filter was later put back on line. The idea was to maximise flow through its filter bed in an endeavour to save one trickling filter rather than lose two.

Testing

On the day of the incident, samples were taken from a number of sites in the STP and also along the sewerage network, working backwards from the Treatment plant until a likely source of contamination was identified.

The following day further samples were taken from the same points.

Additional water samples were also taken from surface waters of the wetland associated with Gills Creek to the rear of the likely contamination source and one of the heavily contaminated pump stations, as well as soil samples from the rear of the likely source of contamination.

Follow-up sampling continued at the Treatment Plant for four days the following week to continue monitoring for petroleum hydrocarbons through the system and potential contaminated discharge into Gills Creek.

Results

Analysis of water samples taken on the day of the event from the Angus McNeil & Harry Boyes Ave pump stations and the inlet works, sediment tank and Pasveer at the STP revealed high concentrations of petroleum hydrocarbons. A mixture of light chain (indicating petrol) and heavy chain (indicating diesel) petroleum hydrocarbons were detected within these samples.

Minor concentrations of petroleum hydrocarbons were detected at the inlet into the tertiary pond, with no detection of hydrocarbons at the discharge point into Gills Creek early on the day of the event. Very minor concentrations of hydrocarbons were detected at the discharge point later on the day of the event and some of the subsequent sampling days.

No concentrations of petroleum related hydrocarbons were detected in the 3 soil boreholes to a depth of 1m at the rear of the likely contamination source.

No petroleum related hydrocarbons were detected in surface waters of the wetland associated with Gills Creek to the rear of one of the heavily contaminated pump stations.

Outcomes of Analysis

The above water sample results confirm the contamination of the sewerage system with a mixture of petroleum and diesel based hydrocarbons extending from the Angus McNeil Pump Station through to the Pasveer at the South Kempsey Sewage Treatment Works. The low concentration and nature of the hydrocarbons detected within the tertiary pond and the discharge point into Gills Creek indicate that petroleum based hydrocarbon contamination was largely or even entirely contained prior to reaching these points. These results combined with the fact that there was no petroleum related hydrocarbons detected in the soil boreholes at the rear of the likely contamination source or in surface waters of the wetland associated with Gills Creek, indicate there was no significant impact to the Gills Creek environment.

Conclusion

The operator who was taken for medical observation was treated for headaches and nausea. He returned to work the following Monday and is now OK.

Other staff onsite also suffered minor headaches due to the volatile work areas, but required no medical treatment.

To date the South Kempsey Sewer Plant has not had any licence breaches since this incident. The Pasveer recovered quickly after the incident and was deemed to be fully operational within a few days. The sludge samples were viewed under a microscope at different intervals over the recovery period to confirm Macleay Water's operations were successful.

It was decided to leave one biological filter off line and maximise the flow into the other. To date this has worked well with the working biological filter producing excellent results.

Looking to the Future!

Council is currently investigating several options for the early detection of petrochemical products in the sewerage system in high risk areas. It is envisaged that the detection systems will allow council to immediately shut down and isolate the affected pumping station and closely monitor and detect the source of infiltration and quickly activate the required response.

The Authors

Peter Anderson is Process co-ordinator, **Barry Young** is a sewer technical officer and **Chris Seam** a support technical officer with Macleay Water (Bus Unit of Kempsey Shire Council). Peter can be contacted at peter.anderson@kempsey.nsw.gov.au

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UNDERBOOL WTP: IN HOUSE DESIGN, CONSTRUCTION AND COMMISSIONING!

Chris Baker

The Underbool Water Treatment Plant project was initiated when the local community requested improved water quality. Underbool (pop 233) is situated in the Mallee region in the far north-west of Victoria. Water is sourced from the Murray River via the Northern Mallee Pipeline, a distance of 140km. High turbidity and colour were the primary issues with the previous untreated water supply provided to the town.

The project, costing approximately $1M, included an upgrade of the 84ML earthen storage and a new 450kL/d multimedia filtration WTP. The earthen storage acts as a balancing storage to compensate for the large seasonal variations in water flow rate received from the Northern Mallee Pipeline. In a deviation from most previous project delivery modes, the Underbool project was designed, managed, and commissioned 'in-house' by Grampians Wimmera Mallee Water (GWMWater) staff. This in-house approach was adopted:

- To minimise the capital cost
- To make use of in-house project design and delivery skills
- To involve operations staff in the project – from conception to commissioning.
- To use local contractors

When we started, the operators just wanted the project to go away. Some quality and communication issues developed because of the engineering Project Manager being in Horsham (GWMWater's Administration/Technical Services Centre); approximately 2½ hours drive from Underbool. As we proceeded, people became more involved and, before long, local staff became more than willing to provide valuable input into developing practical, operational improvements.

Many design concepts were proposed by operations staff and incorporated into the final design. For example, the initial design provided for the unloading of Intermediate Bulk Containers (IBC or bulkie for short) of chemical from trucks and connecting them to the plant via flexible hoses for chemical dosing. Operations staff highlighted that a bulk chemical system would require less manual handling and remove the risk of potential chemical leakage from the flexible hose connections. The chemicals are now unloaded directly from a truck into the bulk chemical storage tanks. Another example is that the proposed boundary fences of the site were shifted, at the suggestion of the operators, to improve access and make the plant easier to operate.

"Chris was just another engineer who drew the short straw," said operator, Terry Donaldson when the project began. "It soon became noticeable that he was prepared to listen to other points of view and to take them seriously. Once we knew he was going to listen, we were happy to be part of it. Now we have a plant that works well."

Operators were also involved in the Hazard Operability (HAZOP) study for the plant. The HAZOP process involves going through the detailed design thoroughly and anticipating or predicting where things might go wrong or where things might have been overlooked. Operator input to this activity simplified the task and eliminated much of the guesswork.

As the works progressed, it became clear that a higher level of site supervision was required. Terry was then seconded for the remainder of the construction and commissioning phase as the site supervisor. Having the future WTP Operator acting in this role ensured quality workmanship, as well as providing practical input that led to efficient plant layout, especially from a future operations and maintenance perspective.

By involving Operations through the design, construction, and commissioning phase, a seamless handover was achieved. After several weeks of 'challenging' commissioning works, the plant produced potable water that met the Australian Drinking Water Guidelines and operated in a reliable manner. The main commissioning challenges included:

- De-bugging the PLC code
- Managing the interface and incorporating changes between Serck SCX HMI system and the Allen Bradley PLC code
- High summer ambient temperatures affecting the reliability of some electrical and instrumentation equipment.

Having our own local operations staff involved proved invaluable to the successful outcome of the project. Practical experience, taking ownership and having the main local operator acting as an onsite supervisor produced a plant that was very practical, reliable and delivered a finished product that GWMWater Operations Group was more than satisfied with.

"As site supervisor, we developed a clear understanding of how the plant was supposed to work," said Terry. "Commissioning became a logical progression once construction finished. So much easier than taking over a plant delivered under an outsourced Design and Construct contract."

Local contractors have developed expertise in delivering GWMWater works and will, in future, be increasingly more valuable for new projects and in maintaining existing infrastructure.

The plant was commissioned in February 2008 and already feedback from the local community is that they are very satisfied with, and grateful for, the significant improvement to the water quality provided by their new water treatment plant.

GWMWater has identified a number of future projects for delivery in a similar manner. Operational staff, not directly involved in this project, are now inclined to be part of these projects.

Acknowledgments

GWMWater would also like to thank our major subcontractors for their assistance with the project:

- Trevor Smith Earthmoving
- Ouyen Mix Concrete and Hire
- Rhino Tanks and Liners
- Acromet
- Alldos Oceania
- Onsite Engineering Services
- Foreman-Sheean Electrical

The author would like to thank Terry Donaldson (WTP operator) and Richard Harker & Dean Peters from GWMWater Operations Group for their assistance, patience, perseverance and keeping their sense of humour throughout the project.

The Author

Chris Baker is a project engineer with GWMWater. He has worked for engineering consultants in delivering similar capital works projects and now appreciates the value of developing in-house design and construction expertise.

COULD THIS HAPPEN TO YOU??? MAKE SURE IT CANNOT

Peter Mosse

At a WTP the alum flow reduced to zero at 1000 hrs due to a blockage in the pump (the dosing pump was still operating and raw water was flowing). No alarm was activated because there was no alarm system on the alum dosing.

By approximately 1130 hrs the filtered water turbidity exceeded 0.5 NTU. This activated an alarm at a control room. As prescribed in the incident management plan the control room operator waited the prescribed 30-minutes prior to contacting the operator. At 1200 hrs the control room operator started to try to contact the plant operator who unfortunately turned out to be in an area with poor mobile phone coverage.

By 1210 hrs the filtered water turbidity had exceeded 1 NTU. At 1230 hrs the control room operator having received no response from the operator, contacted the next name on the contact list. Because of the relatively remote location of the plant, the second contact continued to try to contact the operator without success. At 1245 hrs the decision was taken to shut the plant down remotely at the control room. The filtered water turbidity at that time had reached 1.3 NTU.

Inspection of the utilities incident management system revealed a similar dosing failure in the prior 12 months. The debrief at that time identified the incident as being of major concern and had resulted in actions and timelines being established to critically review the whole alarm philosophy at the plant and to make sure that all alarm settings were reviewed and activated. Work on this had commenced but at the time of the event described above had not been finalised.

BEFORE you start criticising this event, have a look at your own systems. Do you know it couldn't happen in your system? Can you prove it? Do you test it? How often? Is the testing process meaningful? Have you really thought about all the ways your system could fail? Capital projects use HAZOP programs to try to anticipate all sorts of failure modes; has similar rigour been applied to "alarm systems" in your utility?

As Hrudey and Hrudey (2004) state in their landmark book, "You must know your system very well and you must understand all of the ways that things can go wrong. You must have effective and well practiced plans in place for dealing with the many problems, large and small, that can happen if you are to be truly confident about avoiding a Walkerton style disaster".

It is important to recognise that an event such as the one described here could happen. It might not be an alum pump but some other item of critical plant, or just a combination of weather and poor performing filters. Utilities need to actively consider what else could go wrong and plan for that also. Appropriate control measures need to be put in place urgently and tested thoroughly. Incident management needs to be practiced. An integral part of being prepared is being practiced.

Again, in the words of Hrudey and Hrudey (2004), "If after reading about all of the other factors that have gone wrong to cause (disease) outbreaks in 15 different affluent nations you are truly certain that none of this could ever happen to you, then congratulations. However we suspect that those of you most likely to avoid encountering such problems will be those who are willing to believe that Walkerton style problems could happen. The choice seems clear: unwarranted peace of mind or nervous confidence underlying the vigilance necessary to forestall appearance before a Walkerton like Inquiry."

Reference

Hrudey, S.E. and Hrudey, E.J. (2004) *Safe drinking water. Lessons from recent outbreaks in affluent nations.* IWA publishing London.

WORK COVER!!! WHAT ABOUT WATER COVER???

An Inside View to Managing Contamination in Water Storages

David Barry

Water storage tanks come in many shapes and sizes. Most of the tanks within Australia seem to concentrate on water capacity, security of supply and delivery pressure, often at the expense of water quality. Water is simply kept in tanks for too long!

Figure 1. Water tanks come in all shapes and sizes.

The single most important factor should be to store water in a high quality, hygienic environment, yet this is often overlooked during the engineering and design phases.

Most of the problems encountered come from accessories, fitted externally or internally to make the structure workable and safe to the operations personnel. Accessories such as ladders, guard rails, hatch openings, ventilation systems, support posts and pipe work can all contribute to poor water quality. A better understanding of these issues can prevent many problems from occurring.

Figure 2. A heavily corroded ladder access structure is removed from a water storage tank.

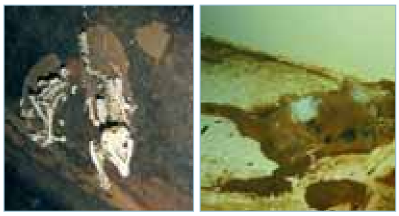

Figure 3. Rotting carcasses are a sure sign that the water storage tanks are not suitable for the storage of water.

Let me give you a comparison - if we operated a grain silo, it would not be acceptable to have stormwater for example, or any form of contamination entering into the structure and damaging the product.

Figure 4. If grain silos were operated like water storage tanks there would be very little grain available for bread!

And yet we have become complacent to these potential hazards in our water storage tanks, relying on adding a little extra chlorine to "make things right". Instead, we should be concentrating on eliminating contamination in all sections of the distribution process, otherwise there is no 'safety net' available if the disinfection system fails.

At present, Safety only extends to the personnel expected to use the site.

Work Cover legislation and the resulting legal implications seem to have blinded managers, designers and safety officers to another important issue – the safety of our water. Why don't we have a "Water Cover" organisation, with the same legal clout as Work Cover to protect the consumers who use our product?

We need a process in place whereby we are also reminded in the media of prosecutions, fines and a loss of entitlements, if water distribution systems are not being managed safely and effectively.

External Issues

We also have a duty of care to prevent access onto our tank sites.

In particular up onto the roof areas, where unauthorised persons can introduce substances into our water storage systems.

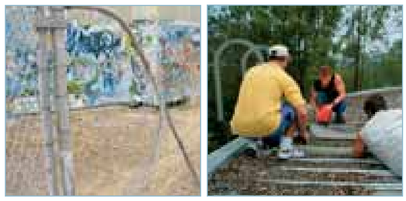

Figure 5. Secure fencing is necessary to prevent access for water quality and prevention of deliberate contamination.

Could a simple videophone movie of an act of vandalism, placed onto a web site cause a complete shut down to the water system? This scenario has already happened in schoolyards and entertainment areas, resulting in the public losing confidence in our abilities to provide safe amenities and services.

Another potential problem: too often, good quality water leaves our treatment plants, only to be degraded by the delivery and storage systems.

Platform areas accumulate debris, which in turn enters the tank.

Figure 6. Accumulated litter and rusty holes ensure access of contaminants to tanks.

Access hatches are not sealed or secured – remember our grain silo scenario?

Figure 7. Hatchways whether open or closed are a common entry point for contaminants.

Ventilation systems allow dust, leaves and small birds and mammals to enter the storage.

Figure 8. Ventilation systems allow access of windblown contaminants and vermin.

Roof gutters will block with debris, allowing them to overflow into the tank.

Telemetry aerials and hand rails attract birds, which deposit faeces around the very areas we should be protecting.

Figure 9. Aerials provide roosting areas for birds and "dumping" areas for faeces.

AND if the easily accessible external areas are neglected, imagine what is happening INSIDE our water storages?

Very few people would be familiar with the internal areas of a tank, and even less would have first hand experience of the operating features in 'real time'.

Protective coatings: Water quality is compromised by contact with corroded materials and personnel are put at risk from unsafe structures.

Galvanised metal has a limited life when submerged in water- the protective zinc coating acts as an anode and quickly deteriorates. Aluminium also corrodes and breaks down when immersed.

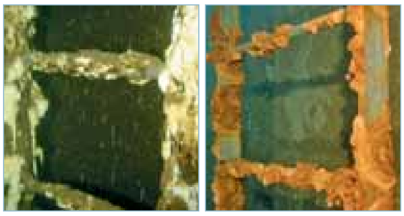

Figure 10. Heavily corroded aluminium and iron ladders do nothing to improve water quality.

Ductile iron pipe work fitted inside concrete tanks is mostly left uncoated and the deterioration is obvious. All corrosion products do nothing to improve the quality of the water leaving the storage.

Appropriate protective coatings are one example of assisting tanks to achieve a realistic design life, while at the same time maintaining water quality. Ladders and pipe work placed inside a steel tank should always coated, along with the wall and floor areas. Shouldn't we be *taking the extra step* when it comes to managing our concrete tanks?

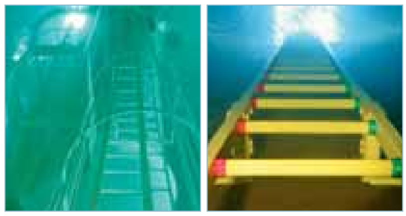

Figure 11. Ladder structures that won't corrode protect water quality.

Pipe work

Water movement into and out of a tank has a significant impact on the product supplied to consumers. Observation of sediment patterns is an important part of determining the best outcomes in pipe work design. Such observations are only really possible by divers entering the tanks.

Top fill inlets can disturb accumulated sediments on the floor areas, due to vertical turbulence within the water column.

Figure 12. Surface filling can create turbulence and disturbs sediment leading to periodic pulse of poor quality "dirty" water.

Wall mounted inlets push water across the floor area, mixing sediments into suspension whenever the fill cycle occurs.

Common inlet outlet configurations have long been a cause of 'short circuiting'.

Figure 13. Common inlet outlets encourage short circuiting and poor water mixing.

Many tanks are having expensive external pipe work upgrades to create separate penetrations, however this does not in itself create an effective pattern of water movement within the tank.

A simple alternative is available - directional nozzles placed over inlet penetrations and positioned correctly, will provide energy efficient water blending at no cost and without sediment disturbance, unlike most mechanical mixer systems.

By placing a 'two way' directional nozzle over common penetrations, inlet water is jetted through the water column to blend the contents effectively. The outlet cycle draws water back through the one way valve with no restrictions to flow rates.

Figure 14. Inlet directional nozzles in non corroding materials provide mixing.

Outlets

Many outlets are positioned either too close to the floor or they have been restricted and contaminated by poorly designed safety screens.

Figure 15. Flush mounted outlets draw any settled material into the outflow.

Outlets need to be raised at least 200mm above the floor to prevent adjacent sediments being drawn into the penetration during peak flows. There should be no adjacent flat areas present, such as surrounding concrete supports that will allow sediments to accumulate and enter the pipe work.

Figure 16. This outlet is raised well above the bottom but still has a small flat area around it for settling of sediment however it is much better than the one shown in Figure 14.

Outlets should be protected as a safety measure. Screen size however, is also important and these should fit closely over the penetration area.

Large screens become passive and this creates an accumulation of sediments across their surface that will contaminate the outgoing flow. Excess areas between screens and penetrations allow build ups which are difficult to remove during the normal tank cleaning process.

Smaller, flat type screens restrict pipe work and offer no suction 'stand off' area against accidental contact by a diver.

The ideal outlet screen should be made from non corroding materials and the surface area of the screen should match the penetration area to allow unrestricted flow. This design of screen will become 'self cleaning' on its external surfaces and will not allow sediments to build up on the inside areas.

Figure 17. Outlet protection that will not impede flow, will not corrode, will not draw in settled sediment.

A suitable 'stand off' area will also provide a safe working environment for divers and maintenance personnel.

Solutions

- Know **what** you are managing – gather existing information and then **quantify** the results. Set up an inspection process to measure, photograph and log all **proven** information. How many authorities have a structured field inspection process that identifies all relevant issues and allows individual structures to be benchmarked against each other or the overall asset group?
- Clients need to draft clear, concise instructions and specifications for construction projects – don't create guide lines that can be misinterpreted or changed by the designers and builders.
- Specify that the appropriate Australian Standards are customised to suit individual projects rather than just state that "all Standards will be complied with"
- Do you cut and paste existing plans that have a similarity, or do you re-invent the wheel? Hopefully a little of both, but you need to know what is working and what is not.
- Take field trips - climb ladders, walk around on platform areas and open entry hatch covers. If you have survived this process, look and listen to the operators - take expert advice and include what is really working into your new design.
- Can we improve on the last project - can we make this current one better for every one involved?
- And finally we need to have all future Maintenance tasks factored in when we design a structure. Just because tasks may only occur every 20 years or so, there is no excuse for neglecting them.

Take the next step –

Learn what is required for maintaining the structure. Try and second guess what MAY be required due to increasing security levels, water quality issues and legislative changes.

And Remember!!!

Things **will not** become easier or more relaxed as we progress into the 21st Century!

The Author

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DUBBO SOFTENS

Peter Catelotti and Dinesh Manivannan

Aerial view of John Gilbert Water Treatment Plant upgrade.

History of Water Supply to Dubbo

Dubbo is a City in the Central West Region of New South Wales. It is known as a *de facto* regional capital city for NSW. Historically the Macquarie River provided water for settlers and the local indigenous population. By 1938, water was sourced from a well in the Macquarie River and a number of wells in gravel drift about half a kilometre back from the river. The water was filtered from the drift, but was hard water; so the two supplies were mixed to yield good water. In 1940 a water treatment plant was commissioned and treated water was supplied to consumers for the first time. In 1981 a new 30 ML/day plant was commissioned. In 1999 Dubbo City Council planned for a major upgrade of the plant to cater for the continuing growth of the city, and the increasing importance of Dubbo as a regional centre. From a population of 20,629 in 1971, it was predicted that the population would and actually has reached 40,000 by 2007.

The Problems

- The need to increase total production
- One of the features of both the river and bore raw water sources supplying Dubbo is its inherent hardness. Previously the bore water component was not treated and was mixed with the treated river water in the chlorine detention tank. This post treatment mixing resulted in an overall increased hardness of the water supplied to town (av 120mg/L $CaCO_3$). One of the objectives was to produce water with a hardness of 60-80 mg/L $CaCO_3$.

The high salinity originated from some of the streams in the catchment, up to 10,000 MicroSiemens/cm, (about one fifth of sea water salinity) at some sites.

New clarifier.

The old filters were not capable of handling the increased turbidity and colour in river water after high rainfall. Filtered water turbidity increased regularly during and after rainfall giving concern for the long-term safety of the water for drinking.

The water had significant periods of poor taste and odour due to algal issues.

After consultation with the community and commissioning of an options report, Dubbo City Council resolved to proceed with the following:

- River water would be used for the bulk (70%) of the raw water source and bore water then used to supplement the remaining (30%) raw water source. All bore water would be aerated to remove carbon dioxide, before being softened along with the river water. Liquid carbon dioxide flashed through a vaporiser with the flashed off gas to be used for recarbonation purposes.
- Capacity would be increased from 30 ML/d to 80ML/d
- Construction of:
  - A new river water intake structure with Johnston Screens that can be periodically cleaned with compressed air backflow.

- A dedicated PAC contact tank would be provided to enhance the removal of algae whilst also improving taste and reducing odours. The tank is fitted with two floor-mounted mixers that ensure thorough mixing of the raw waters with each other and contact with the PAC. Council would retain the option of a future addition of ozone/BAC, to achieve lower usage of chlorine in the water.
- A new clarifier of diameter 33 metres and a depth of 6.4 metres. The clarifier has a flow capacity of 55 megalitres per day and is designed to operate in parallel with the existing 32 megalitre per day capacity clarifier.
- Six (6) new dual media filters. Each filter has an effective volume of 235 cubic metres, 2016 nozzles and a filtering media of 300mm gravel, then 300mm of sand, and finally 1000mm of crushed coal.
- A new tank that combines both a chlorine detention function and a clear water storage tank. Clearwater pumps mounted on top of the new tank pump water to the distribution network.
- Two new solids drying beds. Sludge from the water softening process has a high concentration of lime, typically more than 70%, and this end product is applied as a soil conditioner on acid based agricultural soils to improve their pH quality.

New filters.

Softening

- One of the important aspects of the Dubbo WTP is the softening process. Many operators in Australia are unfamiliar with water softening and the Dubbo WTP is the largest water softening plant in Australia. Hard water has a high mineral content of calcium (Ca^{2+}), magnesium (Mg^{2+}) ions, and possibly other dissolved compounds such as bicarbonates and sulphates.
- Softening involves raising the pH of the water to above 9.5, at which point minerals become insoluble and will precipitate. Some of the softening process options are Lime, Lime-Soda ash (hot or cold), Caustic Soda and ion exchange method. Lime is often the chemical of choice for raising the pH.
- The selection of lime, lime/soda ash, or caustic soda softening is based on cost, total dissolved solids criteria, sludge production, carbonate and non-carbonate hardness, and chemical stability. Dubbo is using the excess lime/soda ash softening process for softening, as excess lime is needed to achieve the precipitation of calcium carbonate (at pH 9.5) and magnesium hydroxide (at pH 11).
- In the Dubbo WTP, the quick lime is slaked using a lime-slaker before being dosed directly into the clarifier with the dosing rates being determined by chemical testing. Soda ash is dissolved in water, then fed into the clarifier along with lime where the clarification and softening processes take place.
- Ferric chloride and polymer are added to the clarification process as the coagulant and coagulant aid.
- The resulting water has a high pH (>10.5) and is still saturated with calcium and magnesium. Carbon dioxide is then sparged into the water to reduce the pH to palatable levels of 7.8 – 8.2 and also re-dissolve the remaining calcium and magnesium into solution.

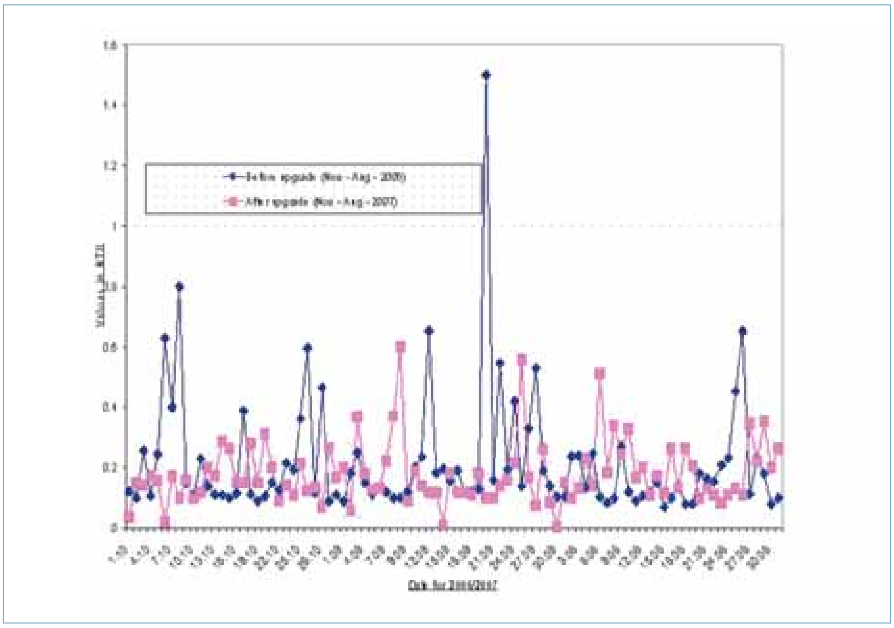

Figure 1. Comparison of turbidity performance of the new and old plants.

Technical Challenges

Technical challenges were faced in order to maintain the standards of drinking water required by ADWG during the implementation stage:

- The quick lime dosing system initially gave some unforeseen difficulties, such as unreliable feed rates, flooding and hangups. This required all staff and operators involved during the operation of the plant to utilise their skills and knowledge in solving the issues. The operators had to keep track of the lime dosing system every day, particularly in the early implementation stage. After a number of modifications to the day-bin, which included installing new air-sparging valves and electronic vibrators to prevent powder compaction, it worked well.

- When the new clarifier was initially brought online we experienced a critical challenge of moderating the high pH after the initial dosing. To overcome the excessive pH, the water from the new clarifier was mixed with the water from the old clarifier and aerated using bore water until we were able to get the pH balanced at normal working levels.

Training and Upskilling Operators

As the old system was also a water softening plant, the staff was experienced in tackling these sorts of problems that were expected in running in the new plant. They were actively involved in the pre-commissioning and testing of the new plant so as to gain experience with the new systems. Operational staff input at the planning stage alleviated a number of problems at commissioning time, as they were able to forecast a number of process problems at that time. Some of these problems were the modifications to the lime day-bin, lime slaker setup, PAC dosing setup, and filters changeover, also the recarbonation basin change to store process water. This resulted in significantly less "hair pulling" later on.

Currently the John Gilbert Water Treatment Plant is the largest lime/soda ash softening plant in Australia and will be capable of meeting the ADWG standards and demands of Dubbo for the next 30 yrs.

Figure 1 shows the performance of the new plant compared to the old plant.

Acknowledgments

Thanks to Manager Geoff Bellingham and Operations Engineer Mike Wilson for providing some valuable information in preparing the paper. Further, thanks to the Treatment Technicians Glenn Clifford, Malcolm George, Patrick Geeves and Councils Mech/Elec Team for discussing the problems they faced during the implementation of the upgrade.

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References

"John Gilbert WTP Options Study", GHD 2002.

Sourcing the salt "How to identify if your catchment is contributing to a salinity problem" by Peter Baker and Michele Barson, BRS.

"Softwater for Red Earth – An 80 ML/d Softening Plant for Dubbo", by Kate Miles, Geoff Bellingham and David Watson – WIOA Conference, Dubbo, 2007.

BEAUFORT AND BLACKWOOD MAINS CLEANED

Nick Martin, John Carr, and David Both

Maintaining water quality in water distribution systems is of paramount importance to reduce the risk of waterborne contamination affecting customers.

Prior to May 2005 the townships of Beaufort (population 1200) and Blackwood (population 700) in central Victoria were supplied with water that was UV disinfected but had no further treatment. The water quality in these networks did not meet potable standards as shown in Figures 1 and 2 "boil water" notices were in place for both Blackwood and Beaufort.

Central Highlands Water's commitment to improve water quality resulted in treatment plants being commissioned in May 2005 and United Water operating the facilities since that time. The final stage in each treatment system is UV disinfection prior to distribution to customers; there is no chlorination in either system. Whilst UV disinfection provides adequate kill rates for waterborne pathogens it does not provide any residual disinfection to avoid regrowth of contaminants in the water supply network. A key component of the contract for operating the treatment facilities was mains cleaning of the networks. The initial type and frequency of cleaning for each town is shown in Table 1. A 12 month trial mains cleaning program was instigated upon commissioning. The results of the trial were evaluated in June 2006.

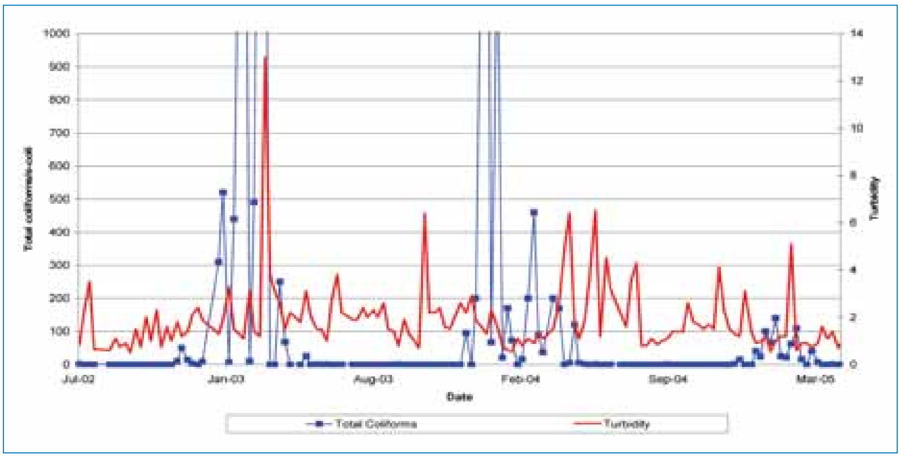

Figure 1. Coliform and turbidity results for Blackwood.

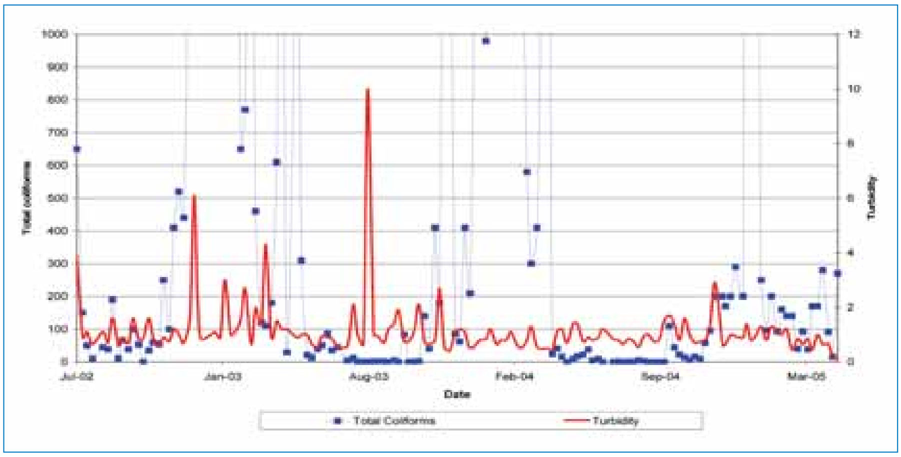

Figure 2. Coliform and turbidity results for Blackwood.

The Beaufort water distribution system is an old network with the oldest main dating back to the early 1900's. The majority of pipes are asbestos cement. The Blackwood system is newer, circa 1983, with the mains all PVC.

Since the CHW contract specified air scouring and mains disinfection with liquid chlorine, purchase of air scouring equipment and back up liquid chlorinator was required. A 268 CFM air scouring unit was purchased for this work.

Table 1. Initial Mains Cleaning Schedule.

Cleaning Technique	Extent	Main sizes (mm)	Frequency
Beaufort			
Flushing	20 dead ends	75 – 100	Every 2 months
Air Scouring	25 km	75 – 300	Yearly
Swabbing	5 km	300	Yearly
Disinfection	30 km	75 – 300	Every 6 months
Blackwood			
Flushing	25 dead ends	100	Every 2 Months
Air Scouring	16 km	100 – 150	Yearly
Disinfection	16 km	100 - 150	Every 6 Months

Mains Cleaning In Beaufort and Blackwood

As with any "planned" maintenance, planning is the key to a successful outcome. The planning phase of the Beaufort and Blackwood exercise commences a few months before hand. The schedule is now well documented and plans of each cleaning block are kept. However, these plans need to updated prior to each exercise to take account of any network changes. The critical customers in each town need to be contacted at least one month prior to ensure that they will not be unduly affected. All customers are contacted via mail by CHW before any work commences and each customer is notified 2 days prior to their individual supply being cleaned. Difficulties have been experienced, particularly in Blackwood, with quite a few customers not having appropriate places to lodge the cleaning notification.

The primary trunk main feeding each town is the first to be cleaned. This is done at night since during this phase the entire township is without water. When key customers, such as hospitals, restaurants and hairdressers, are affected by any cleaning activity, and they do not have dual services, temporary pressurised supplies are provided. The service to each customer affected by a cleaning run requires isolation prior to commencing that run to avoid dirty water getting to the customer during air scouring and highly chlorinated water during the disinfection stage after the air scour. The customer is required to isolate their boundary cocks themselves, however each service needs checking as approximately 30% of customers do not isolate their service.

The major equipment used for air scouring is a compressor unit and air filters, filter bags, lay flat hose and standpipes. Figure 3 shows the trailer mounted air scouring unit and Figure 4 shows the filter bag in use.

Figure 3. Trailer mounted air scouring unit.

Figure 4. Filter bag being used to filter the water coming out of the hydrant.

Following each air scouring run, the main requires disinfection. This is achieved by injecting sufficient 12.5% sodium hypochlorite solution into the main to achieve a minimum 10 mg/L free chlorine residual after 3 hours. At the end of the 3 hours the highly chlorinated water needs to be removed from the main. This water needs to be dechlorinated prior to discharge to the environment. This is achieved using a sodium thiosulfate solution injected into the discharge stream. An alternative method of dechlorination is to pass the discharge water through a diffuser containing ascorbic acid tablets, however, care must be taken with this method as it is not as affective at reducing chlorine at very high concentrations and the level of chlorine in the discharge must be checked. Figure 5 shows the mains dosing trailer, Figure 6 the temporary supply trailer and Figures 7 and 8 the two dechlorinating methods.

Treated water is discharged to stormwater during mains cleaning and disinfection processes however it can be recycled back to a reservoir using tankers, however the cost is significant. This process is very impractical if it is expected to capture all of the discharged water as tankers can not keep up with the cleaning process.

Figure 5. The disinfection trailer.

Figure 6. The temporary service trailer.

Figure 7. The dechlorination diffuser.

Figure 8. High concentration dechlorinator.

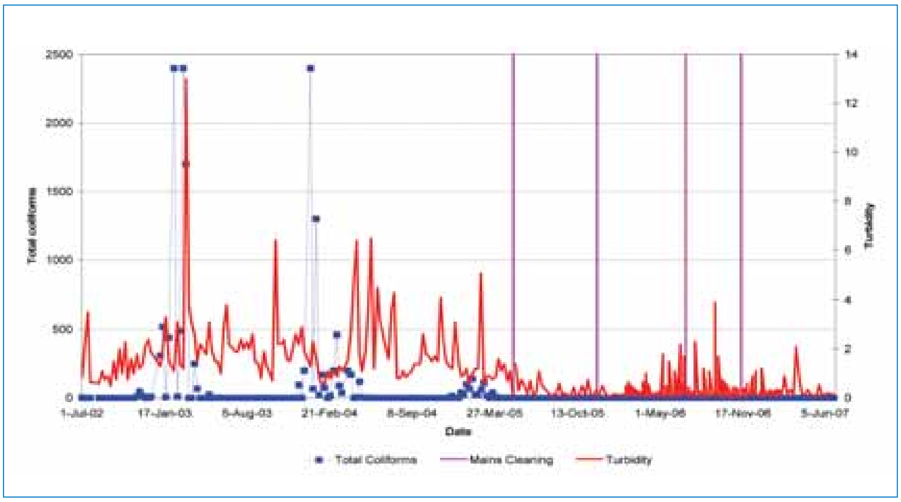

Figure 9 Blackwood Network Total Coliforms and turbidity in the Blackwood network before and after the mains cleaning program.

The mains cleaning exercise in Blackwood takes 10 days to complete. In Beaufort approximately 5 km of the 300 mm diameter main feed to the town requires swabbing once a year and disinfecting twice a year in addition to the air scouring and disinfection. This is undertaken at night and is done before the rest of the town is air scoured. The mains cleaning exercise in Beaufort takes 15 days to complete.

Results

Figure 9 shows the turbidity and total coliforms results before and after the treatment plant commissioning and the mains cleaning program in Blackwood. It can be seen that the network turbidity has decreased since the introduction of the treatment plant and the mains cleaning program.

The figure shows that the combination of water treatment, UV disinfection and mains cleaning has been successful in maintaining adequate bacteriological water quality and as a result the boil water notice in Blackwood was lifted in June 2006.

The situation in Beaufort was a little different. Figure 10 shows the monitoring data for Beaufort from July 2002 to June 2007. The turbidity has improved since the treatment plant came on line in 2005, however total coliforms have been detected in the network between May 2005 and June 2006. This indicates that the mains disinfection trial had not been successful in maintaining adequate bacteriological water quality in the network.

The trial was extended for a further 12 months with cleaning carried out at twice the frequency of the original program however as shown in Figure 10 total coliforms still persist in the Beaufort network. The boil water notice remains in place. A possible reason for the difference between the results for the two towns is that Beaufort has an old water supply network, with a high failure rate, compared to Blackwood. It consists of various pipe types which have, for the majority of their life, transported untreated water, it is not unexpected to see the results obtained.

Conclusion

UV disinfection, in conjunction with treatment and appropriate maintenance practices, can be successful in maintaining adequate bacteriological water quality in water supply networks. The success rate will depend on the age and type of water network and the maintenance practices. Trials on a case by case basis are required to establish cleaning frequencies, costs and labour requirements. Public consultation is extremely important for a mains cleaning exercise and when considering options for water supply, particularly if passing on costs to customers.

Acknowledgments

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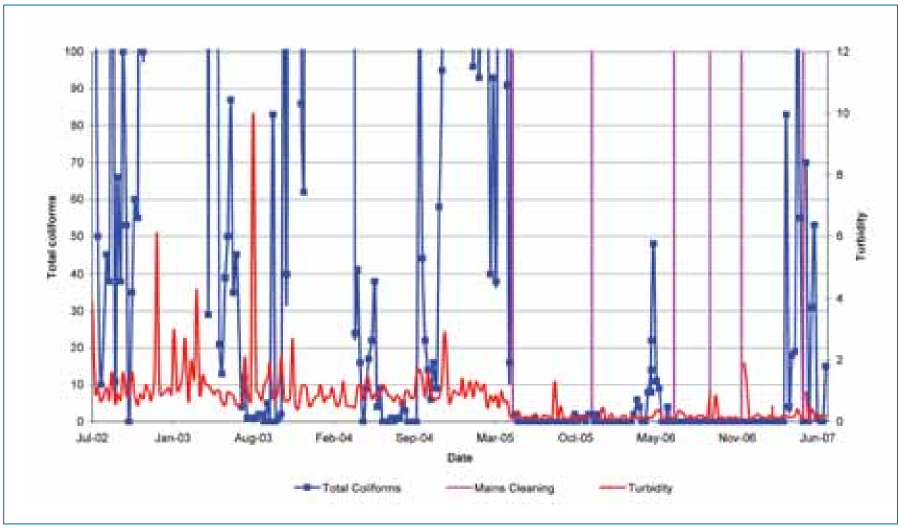

Figure 10. Beaufort network Coliforms and turbidity.

WATER CORPORATION TRAINING: A HANDS-ON APPROACH

Rob Namestnik

The WA Water Corporation's dedication to training water treatment process operators has been a priority for some time. Unlike the situation in some states such as Queensland and Victoria, there are no private external training providers for water treatment in Western Australia. The Water Corporation has small, dedicated team who design, develop and deliver water treatment training across the state. The Water Corporation has no Registered Training Organisation (RTO) status itself but instead carries out training and assessment services under the auspices of Challenger TAFE and Central TAFE.

The first water treatment training module, Basic Water Treatment (at Certificate II level), was commenced over one year ago and has been delivered to staff at the metropolitan schemes but also as far as Karratha in the north and Albany in the south.

Topics covered during the training include the physical and chemical properties of water, its ability to act as a universal solvent, chemical symbols, terminology, chemical compounds used during water treatment and chemical reactions related to water treatment that allow for the removal of impurities found in typical raw water sources. The type of treatment necessary is related to the characteristics of the raw water found at different locations in Western Australia and the requirements of the Australian Drinking Water Guidelines.

The impact of WA's drying climate and associated reduced rainfall on the quality of water supplies is discussed along with water use patterns by the community. The whole treatment process from catchment to tap is discussed including the use of multiple barriers. The focus is then shifted to water treatment processes covering pre-treatment, oxidation of various impurities, coagulation and flocculation, sedimentation and clarification, filtration, colour and organics removal, pH correction, disinfection, fluoridation and storage.

To ensure the course is interactive and relevant, a range of laboratory activities and simulated water treatment processes are included, which together provide a sensible framework to reinforce concepts covered by the underpinning knowledge.

Over seventy operators have successfully completed Basic Water Treatment and the course is so popular that non-operators are lining up to bolster their knowledge of the industry.

Figure 1. Testing the effect of coagulants on pH.

Figure 2. Testing the organics removal efficiency of powdered activated carbon.

Figure 3. Simulation of a basic water treatment process.

Figure 4. Carrying out filter optimisation tests – backwash times and sludge retention.

Whilst delivering Basic Water Treatment, the Certificate III course that we have named Applied Water Treatment was developed. The first delivery session was piloted in April 2008 and was well received by the operators. Several staff from Karratha were flown to Perth to work with staff from the Jandakot, Mirrabooka and Wanneroo water treatment plants. The pilot was held at the Wanneroo WTP, one of Perth's largest groundwater treatment plants that uses the unique MIEX© process which removes organic impurities.

Applied Water Treatment specifically covers the monitoring and control of critical water treatment process such as coagulation and flocculation, sedimentation and clarification, and filtration. Wherever possible, activities described in Bruce Murray's and Peter Mosse's Practical Guide series are used. In particular, a set of filter optimisation activities was written to compliment the *Practical Guide to the Operation and Optimisation of Media Filters.* During the Applied Water Treatment pilot training session, a number of these filter tests were used with great success.

The operators were keen to learn about ways in which they could determine filter performance, and just as importantly, maintain records for each filter over the long term to monitor any deterioration over time.

Equipment was designed and constructed to take filter media core samples, measure bed expansion and test for media fluidity. Since all the filter tests are conducted from the concrete apron above the filter media, various attachments connect to a long handle capable of reaching six metres to the media surface were constructed. The long handle is made up of many 270 mm lengths of 32 mm diameter PVC pipe that allow the kit to be transported with relative ease when disassembled.

Correct clarifier operation was also determined by estimating the optimum surface loading by taking a large influent water sample from the clarifier reactor or recirculation zone. The samples were subjected to laboratory tests including successive, timed settling, turbidity and true colour tests.

It appears that the Applied Water Treatment training module is well on the way to becoming another success story in terms of providing our operators with the knowledge and skills to optimise their water treatment process. This will also allow operators to tackle future water quality issues should they arise as our raw water sources change in the years to come.

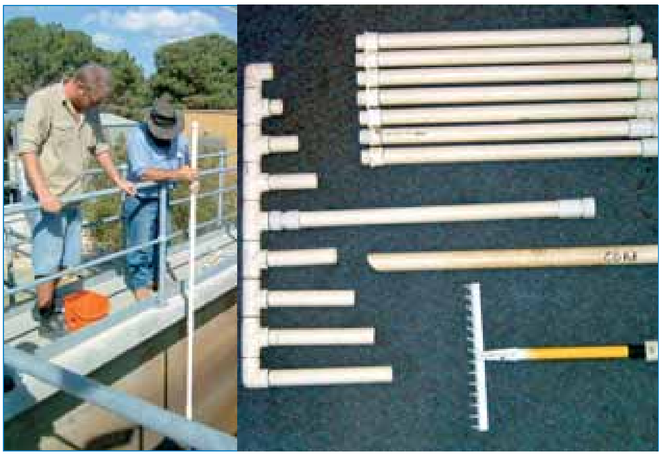

Figure 5. Portable filter media test equipment being tested (left) and disassembled (right).

Figure 6. Determination of optimum clarifier surface loading.

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STRATIFICATION SOLUTIONS

Chris Perks

Dealing with stratification in water supply reservoirs is a common problem for many water authorities. Failure to identify and control stratification can compromise water treatment operations, meeting regulatory standards, customer expectations, environmental flow releases and potentially isolate an affected reservoir from a supply system.

The development of different layers within the profile of a water body with different physical and chemical characteristics is known as stratification. Without intervention, the severity of stratification commonly increases.

This report describes the development of a program at Central Highlands Water (CHW) in Victoria to monitor stratification and the effectiveness of applying aeration to control stratification in Musical Gully Reservoir. Musical Gully reservoir is a relatively small reservoir (228 ML) that supplies the township of Beaufort in western Victoria.

Basic Characteristics of Stratification

Figure 1 shows the key characteristics that are typical of a fully stratified water body.

The most important features to note are:

- A surface layer of aerobic water known as the epilimnion. This layer is relatively warm and high in dissolved oxygen (DO) (commonly > 7 mg/L). In this zone, temperature and DO levels tend to be maintained by the penetration of sunlight and mixing created by wind.
- A deeper layer of largely anaerobic water, known as the hypolimnion, that extends upwards from the bottom of the reservoir. This layer is relatively cool and low in DO (commonly <3 mg/L).
- A very thin layer of water, known as the thermocline, where a rapid change in temperature and DO occurs in between the epilimnion and hypolimnion.

Stratification becomes more severe during warmer months of the year when the intensity and duration of sunlight increases, and mixing from reservoir inflow decreases due to reductions in streamflow. As the severity of stratification increases, the contrast in water temperature and DO between the epilimnion and hypolimnion tends to become more pronounced, and the position of the thermocline tends to rise, effectively increasing the proportion of the hypolimnion.

Implications of Stratification for Water Authorities

Failing to undertake adequate monitoring and developing an ongoing understanding of water quality characteristics within the profile of a reservoir can create considerable problems for water authorities. One of the most common problems is that the thermocline rises above the designated offtake level and water of poor quality is drawn from the reservoir. Some of the most common problems associated with reservoir stratification are:

- Water treatment processes can become difficult to manage and the cost of treatment can increase substantially.
- The ability to meet drinking water regulatory standards can be compromised.
- Water odour can become a problem, particularly as a result of the release of hydrogen sulphide.
- Manganese and iron levels can be higher in anaerobic water. If these are not reduced during treatment, clothing items can become stained during washing as the manganese and iron react with washing detergents.
- The likelihood of receiving customer complaints can increase.
- Environmental flow releases can become jeopardised as the release of cold or anaerobic water can have adverse impacts on downstream river health.
- Adverse affects on the reservoir ecosystem as a result of low DO levels. These can include fish kills and algal blooms.
- In extreme cases, a severely stratified reservoir may potentially need to be isolated from a water supply system due to poor water quality.

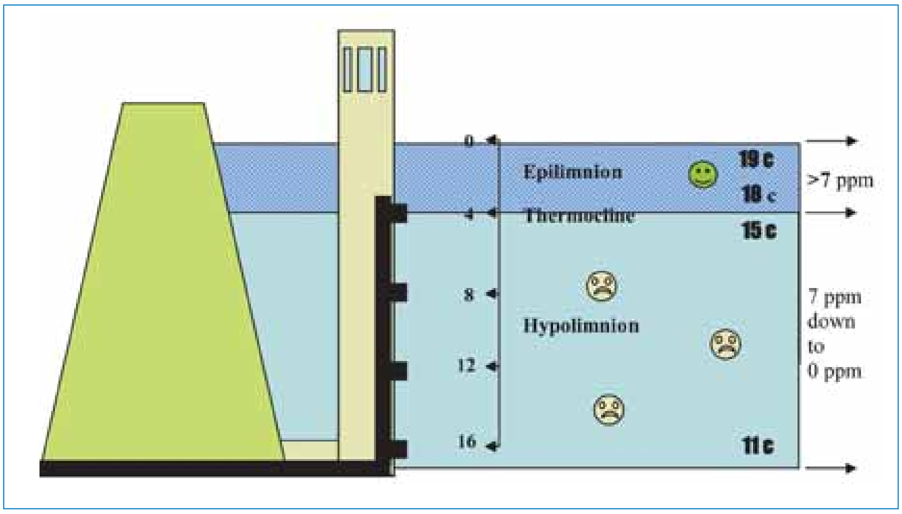

Figure 1. Schematic of a fully stratified reservoir.

Developing an Effective Monitoring Program

Developing an effective monitoring program and undertaking relatively simple analysis of results serves as an effective tool to facilitate a strong understanding of changes to reservoir profile characteristics throughout the year.

The key to the development of any monitoring program is to identify the level of data collection required to provide adequate data for meaningful analysis, while considering the available resources, funding and level of training required.

In recent years, CHW have developed a basic, but effective monitoring program where field staff collect and analyse important reservoir profile data on a routine basis to help improve reservoir management. Some of the key features during the development of CHW's reservoir profiling monitoring program included the following.

- Starting with a basic, but flexible monitoring program to enable fine tuning over time.
- Investigation and purchase of an appropriate DO and temperature sensor. Features that were considered most important included repeatability of results, ease of use and calibration, durability, length of cable, water resistance, ability to log data, and adequate technical support for staff training and repairs.
- Considering availability of resources such as boating equipment, trailers, vehicles, safety equipment, level of staff knowledge and training.
- Allocating a designated day for field parties to specifically undertake reservoir profiling.
- Selection of reservoirs for inclusion in the monitoring program and identification of a specific location within each reservoir for monitoring.
- Commencing with monthly monitoring at all selected reservoirs to identify seasonal trends in reservoir profile characteristics.
- Obtaining readings at one metre intervals throughout the profile of the reservoir.
- Adjusting the monitoring interval at specific reservoirs over time to provide more detailed information (i.e. fortnightly or weekly monitoring may be beneficial when stratification is likely to become more severe).
- Developing and maintaining adequate computer files to easily store and analyse monitoring data, and training field staff to use the files with skill and confidence.
- Developing a reporting system to ensure that any abnormalities, trends or changes in reservoir profile are quickly reported to the co-ordinator.

Over the past few years, CHW field staff have shown that they can conduct all aspects of the monitoring program with great success. The field staff involved with the monitoring program have developed important field monitoring and data collection skills, greatly increased their knowledge of trends in reservoir profile, and displayed that they can detect the early onset of stratification.

Figure 2 shows the change in dissolved oxygen levels in relation to the off-take levels of Musical Gully Reservoir as the 2005-06 water season progressed from winter through to spring.

The figure clearly shows the onset of stratification by late spring and the potential for water that is low in DO to approach the level of the upper outlet (Outlet 1) if stratification was to become more severe during summer.

Introducing Stratification Control Measures

When monitoring detected the onset of stratification, CHW have introduced aeration as a control measure in some reservoirs.

After the 22nd November 2005, aeration was introduced to Musical Gully Reservoir in an attempt to prevent the thermocline from approaching Outlet 1. Figure 3 shows the DO profiles throughout the summer of 2005-06 with the aerator in use.

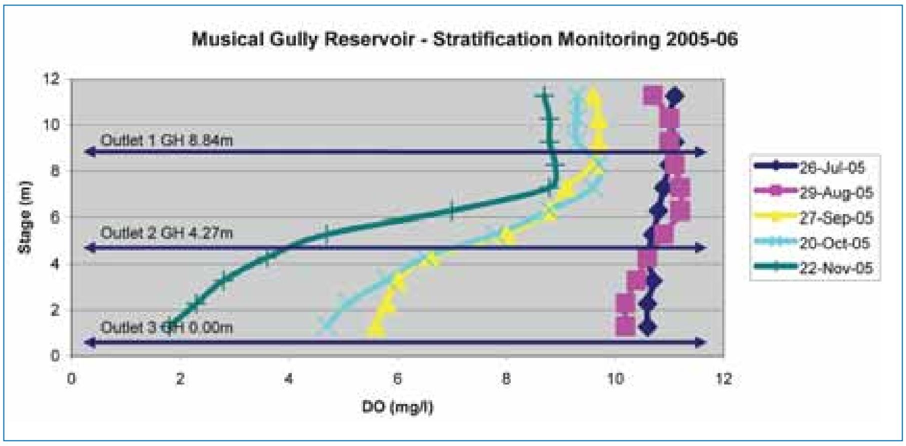

Figure 2. DO profiles at Musical Gully Reservoir during the Winter and Spring of 2005.

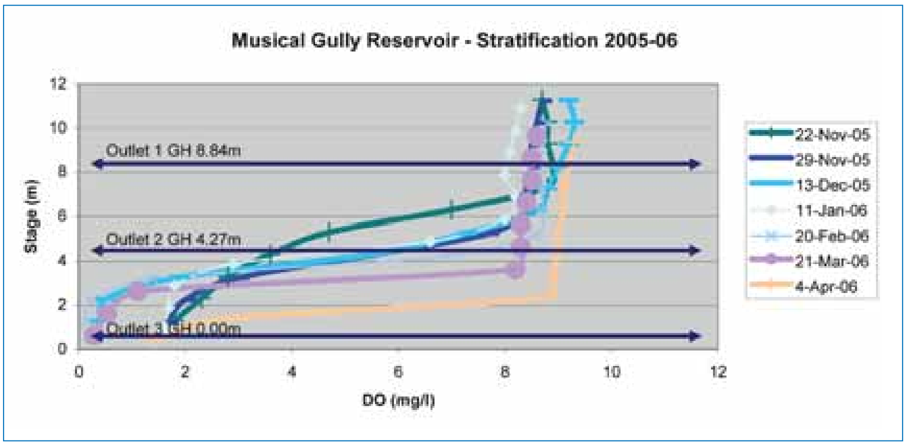

Figure 3. DO profiles at Musical Gully Reservoir during Summer 2005-06.

Figure 4. A portable air compressor installation at Musical Gully Reservoir.

The figure shows the immediate lowering of the thermocline after the introduction of aeration on the 23rd November 2005 (indicated by comparison of the dissolved oxygen profiles taken on the 22nd November and 29th November 2005), and the ability of aeration to keep the depth of the thermocline down throughout the summer.

In recent years, CHW have used both electrical blowers (permanent installations) and diesel fuelled air compressors (temporary installations) to aerate reservoirs (Figure 4). The effectiveness of aeration appears to depend on the size of reservoir and the extent of aeration but appears to be quite effective in relatively small reservoirs, e.g. Musical Gully Reservoir has a capacity of 228 ML, and the use of an air compressor has proven to be successful in keeping the thermocline at depths that are safely below the upper off-take level.

The combination of collecting monitoring data and the use of aeration have provided CHW with a great deal of confidence in regard to the quality of the water that was being drawn from Musical Gully Reservoir throughout the entire water season.

CHW have introduced aeration to other relatively small reservoirs with similar success and are now looking to install more permanent aerators to keep operating costs down.

The monitoring program has allowed field staff to:

- understand water quality within the profile of a reservoir in relation to off-take levels
- identify the early onset of more severe stratification, where poor quality water comes closer to the surface of a reservoir
- avoid drawing or releasing poor quality water
- provide timely recommendations for the introduction of stratification control measures.

CHW's monitoring results indicate that the use of aeration in relatively small reservoirs has helped to prevent the stratification layer from rising during summer months. As such, aeration has proven to be an adequate stratification control measure in certain reservoirs and has provided some important benefits including risk minimisation, greater confidence in water treatment processes, enhanced water quality management, and improved efficiency in reservoir management.

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